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EFFECT OF DROUGHT ON KANSAS WATER SUPPLY PRACTICE

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EFFECT OF DROUGHT ON KANSAS WATER SUPPLY PRACTICE

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ABSTRACT

Kansas and neighboring states to the east, south and west suffered from a severe rainfall deficiency in 1952-54. Problems of maintaining bacterial and chemical quality are discussed with references to specific cities, and emergency measures are described which kept cities supplied with potable water. The severity of the 1952-54 drought is compared with previous droughts, and comments are offered as to its effect upon current waterworks design practice. Brief references are made to stream sanitation problems caused by the drought, although these are mentioned primarily as they affect public water supplies.

On Friday the 13th, 1951, one million second feet of water were flowing from two Kansas rivers, and floods had knocked out 37 city water supplies. Less than three years later, 26 communities were out of water. Portable water filtration units were used, and other emergency measures were taken to quench the public thirst.

Several periods of drought occurred in Kansas before precipitation records were kept.(1) Two were during settlement of the state and had a profound influence on events of that time. The first extended from 1859 to 1868 and caused 40,000 of the 100,000 early settlers in eastern Kansas to abandon their claims. The second, in 1887, caused the settlement boom to collapse and banks and business houses to fail. Some of the western counties were almost abandoned as thousands of persons left Kansas. Precipitation data are available since 1890, and the average annual rainfall since that date is shown in Figure 1.

The current drought began in 1952 and has continued into 1955. During this period, 62 cities have provided emergency water supplies at a total cost of $4,300,000. Farmers spent an additional $7,400,000 to haul water during the first 10 months of 1954. Of the 420 municipal supplies in Kansas, 175 have been short of water and 169 restricted water use by rationing. Most of the distress occurred in eastern Kansas where ground water is scarce and many cities depend upon surface sources. During this period, competition for water has been keen, with some conflicts occurring between cities and farmers. Upstream irrigation has threatened several city water supplies.

Effect of Drought on Quality

Special care was taken to assure that safe water was maintained in those

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cities where shortages were occurring. The State Board of Health asked each city to check the chlorine residual in the distribution system daily, and an expanded, more frequent bacteriological sampling program was undertaken. On the basis of the bacteriological results, it is apparent that some difficulty was encountered, particularly in those systems where water pressures fluctuated or were maintained only a part of the day. Experience has demonstrated that back siphonage does occur, particularly in the higher sections of the city, when water pressures fluctuate drastically or drop to near zero.

While the number of bad samples increased, all of the surface supplies continued to meet the U. S. Public Health Service Drinking Water Standards. This indicates the extreme care which was taken by waterworks personnel to guard water quality. The quality of raw surface water was greatly improved by the state's stream cleanup program which was started in 1948.(2)

As the water shortages developed, and as rates increased, hundreds of persons drilled wells on their city lots. Although theoretically these wells were for lawn watering, and other uses not permitted under city restrictions, some of the water was used for drinking purposes. In general, this water was not of good bacteriological quality, and there was always the possibility of an outbreak from a sewage-polluted well. Preventing the connection of these wells with the city system required special supervision in some cities.

The drought had an important effect upon the chemical quality of water, particularly that in streams. The decline in the water tables and further lowering through pumping caused some deterioration of chemical quality in ground water, but this has not been serious. The important deterioration occurred along the Kansas, Neosho, Marais des Cygnes and Verdigris rivers. Both natural and man-made pollution contributed to this condition.

The oil industry in Kansas produces 65,000,000 gallons of brine daily, with an average sodium chloride concentration three times as great as that of sea water. Of this amount, 15 million gallons is used for secondary recovery of oil, 45 million gallons goes to deep disposal wells, and five million gallons flows to the streams, seeps into the underground waters or leaches out near the surface. This load combined with pollution from natural salt deposits makes chloride the most important, single chemical pollutant so far as Kansas water supplies are concerned.

Detergent pollution caused deterioration in chemical quality along the Neosho River, as shown for a period of low, but not minimum, flows in Table 1. Beginning with Council Grove, 12 cities use this water, treat it and release it for the next city downstream. Several times during 1953-54 the total flow at each city's waterworks intake did not exceed the sewage flow from the upstream community. This contributed to a build-up in detergents sufficient to disturb treatment processes and leave as much as 6 parts per million of detergent in the finished water. Similar conditions occurred on the lower Marais des Cygnes River at Osawatomie.

Russell, a city of 7,000, was forced to develop an emergency supply from the Smoky Hill River, eleven miles distant, when its regular source of supply failed. Water from the river was pumped into a small reservoir of fresh water near the water plant. Chlorides in the river water increased to 3200 parts per million during the period of pumping and the chlorides in the treated water gradually built up to 1600 parts per million. Local physicians became alarmed and forbade patients with certain cardiac and kidney ailments to use the city water.

Fortunately, the Bureau of Reclamation had 120,000 acre feet of fresh water, for which it had no use, in storage 40 miles upstream. After

TABLE 1. Total Anionic Synthetic-Detergent Content
Neosho River, March, 1953

City	Synthetic-Detergent Content-ppm			
	Raw Water	Tap Water	Treated Sewage or Sewage Outfall	Below Sewage Plant or Outfall
Emporia	0.8	0.6	15.0	1.4*
Burlington	0.8	0.5	33.0	1.0
LeRoy	0.8	0.7	27.0	1.0
Iola	0.7	0.5	20.0	11.0#
Humboldt	1.0	1.0	34.0	1.2
Chanute	1.0	0.9	29.0	1.9
Parsons	0.9	0.8	22.0	--
Oswego	1.2	1.0	4.1	1.4
Chetopa	--	2.2	4.6	1.2

*Cottonwood River
#Creek before entering Neosho River

negotiations between official agencies and the Bureau failed, an agreement was reached at the highest political levels allowing sufficient water to be released to reduce the chlorides at the Russell emergency intake to 500 parts per million.

El Dorado and Augusta developed wells along the Arkansas River and built 37 miles of pipeline to bring the water to their treatment plants. It was known that the chemical quality of the water would be poor. The chlorides were 24 times as high in the new emergency supply and the sulfates increased from 38 to 244 ppm. In addition, the cone of influence of the wells extended into the river sufficiently to cause the river water, containing the wastes from Wichita about 13 miles upstream, to flow toward the wells. The detergent concentration in one well reached 13 parts per million, and detergents in the finished water increased to 8 parts per million, sufficient to cause froth on water as it was drawn from the tap.

Typical of the changes in chemical quality among cities which had to go to less satisfactory ground water sources was the change in sulfate content of the Herington treated water from 167 parts per million to 1038 parts per million. At Kiowa the total hardness more than doubled and the sulfate increased from 177 to 779 parts per million, while at Cheney it increased from 33 to 860 parts per million.

Although such changes in chemical quality could not help but cause some intentinal disturbance, there have been no serious complaints from local physicians. This compares with experience in the Ohio River Valley during the 1930-31 drought when intestinal disorders involving 4,000 persons were blamed on the chemical and physical quality of the water.(3)

The drought has caused many problems of water treatment. With decreasing dilution, the detergent concentrations increased, and algae growths flourished in the relatively clear water. In cities where surface supplies failed and temporary wells were developed, the harder water was much more difficult to treat. In numerous cities chlorination capacity had to be increased, and activated carbon was fed to combat tastes and odors.

In the winter of 1953, Osawatomie faced a severe problem of detergents in its river water supply. The raw water was clear but showed about 50 parts

per million of color. According to Culp and Stoltenberg,[4] it also possessed a strong fishy taste and odor. The coagulation and settling basins acted in reverse, both being covered with several inches of floating debris which ordinarily would have settled to the bottom. Froth accumulated on the coagulation basin, but the most serious interference was with sedimentation. Under the worst conditions, approximately 70 per cent of the coagulated material floated to the top of the basins. Ten per cent settled to the bottom, and 20 per cent was carried to the filters. Filter runs were reduced from 100 to 7 hours, rising gas bubbles were observed throughout the treatment process and the finished water was colored with a strong, disagreeable fishy taste. The use of activated silica, 10 parts per million of chlorine and 25 parts per million of alum aided in reducing the problem. Good color removal was obtained, much of the floating material was eliminated and filter runs were increased to about 16 hours. Odor in the water was eliminated and the fishy taste was replaced by a less pungent taste described variously as rancid, bitter or soapy.

El Dorado, on the other hand, had no difficulty with sedimentation or filtration and only minimum problems of taste and odor. While its raw water contained comparable concentrations of detergents, it was free from turbidity and organic material.

Detergent problems were also encountered at Russell, Augusta and Erie.

At Wichita, a well on the opposite side of the Arkansas River from a sanitary landfill pumped water from under the landfill when the river went dry. This water, which was offensive even at high dilutions, had passed through the water purification plant at night and was well distributed over the city when the residents awoke the next morning.

At least 3 cities served by impoundments, suddenly had water which turned brown when chlorinated. Investigations revealed that the bottom of the impoundments had become anaerobic, causing manganese to be taken into solution. This was caused by excessive organic material in the lake. Prechlorination, to 1.0 parts per million minimum after one hour contact, to oxidize the manganese before lime was added, eliminated this problem.

Emergency Measures Used

The emergency measures taken to provide the cities with water have varied from city to city, depending upon local conditions. Burlingame, Carbondale and Olathe hauled water in railroad tank cars. Thirty cars previously used for petroleum products were specially sterilized and made up into a train for Olathe. State Board of Health engineers supervised the preparation of some of the cars. They were steamed for 24 hours, then one foot of water was added to each tank with 2-1/2 lbs. of sodium hypochlorite. The sides of the cars were brushed down with chlorine solution, the cars drained, steamed another hour and finally rinsed with city water. The water supplies in some cities downstream from federal reservoirs, and in particular the Fall River Reservoir, were maintained by releases from the reservoir conservation pools. Some of the releases were made from Harlan County and Cedar Bluff reservoirs to dilute streams high in chlorides and sulfates.

Gasoline truck transports of 4,000-gallon capacity were used to haul raw water for Osage City from the Marais des Cygnes River, 13 miles distant. This continued for eight months during one period.

At the Governor's request, the State Board of Health engineers studied the feasibility of constructing pipelines from some of the distressed cities to the

nearest sources of water.(5) These sources were from 6 to 12 miles distant from the cities studied. Federal Civil Defense officials expressed interest in supplying the pipeline and pumps to transfer water to storage near the respective treatment plants. This was finally done at Olathe to take advantage of a shower in an adjacent watershed. The pipe was assembled quickly, but the pumping equipment was not well suited to continuous use. Also it did not lend itself to synchronization where pumps were needed in series.

Water purification units, consisting of large canvas tanks and a truck-mounted pressure filter with chlorinator, were borrowed from the U. S. Public Health Service and used at six small cities. This equipment, with 100 gpm capacity, was particularly helpful to small communities where the well supplies had failed and surface water was still available. Usually two tanks were used with batch treatment and coagulation. Pumping of water into the tanks induced enough turbulence in most cases to provide mixing. Where it did not, a gently idling outboard motor was quite effective.

At least one city pumped from below the sewage plant outfall to the waterworks intake. A coffer dam was placed between the outlet and the pool from which the water was pumped to prevent commingling of sewage with the water. Several cities discussed the possibility of treating sewage plant effluent mixed with a limited amount of raw water, but this was not done.

Two refineries and El Dorado found a novel way of transporting water from Wichita, some 34 miles distant. They arranged to pump city water through a refined products pipeline from Wichita when the pipeline was not being used to transport refined oil products. Pressures in excess of 1,000 psi were used, and high velocities were maintained. Even slight corrosion greatly reduced the carrying capacity of the pipe. To keep this interference to a minimum, a mechanical pipe cleaner was run through the line each day to remove the tuberculation. The water was used by the two industries although plans were made to pass it through the city water treatment plant for domestic use if necessary.

Conservation Methods When Supplies are Inadequate

Strict conservation measures were invoked in cities most seriously affected by the drought. These were put into effect by ordinances while cities less seriously affected used various voluntary methods of conservation. Voluntary rationing frequently permitted lawn watering on alternate days of the week during specified hours.

Where city ordinances served as the basis for the rationing, two general methods were used as shown in Table II. The first provided fines for the ordinance violation, whereas the second attained rationing through a specially designed rate schedule. The cities which adopted a special rate schedule for drought conditions frequently sold the first 2,000 gallons of water at the lowest price with the rate increasing as larger quantities were used. Rates of $3.00 to $5.00 per thousand gallons were adopted in a number of cities, and at Olathe the average domestic water bill for March, 1954, was $20.00. While this method did not make the news as readily as the occasional large fine of someone who had washed his car in violation of an ordinance, it was very effective.

The biggest single benefit of rationing was in the reduction of peak daily water demands; under rigid restrictions the hourly variations in water usage rate were reduced. Water consumption on peak days was reduced as much as 70 per cent, whereas the average water use over a period of several

TABLE II. Methods of Restricting Water Use

Source	Total Municipal Supplies	Number Shortages 1953-'54	Conservation Methods		
			Voluntary	Compulsory	Higher Rates
Surface	68	40	14	23	3
Ground	358	135	79	55	1
Total	426	175	93	78	4

months was reduced by 25 to 30 per cent. Voluntary rationing produced reductions in average daily use up to 25 per cent. Billings reports that the average(6) daily water consumption in Texas cities was reduced as much as 70 per cent by compulsory rationing.

The use of reduced pressures as a means of conservation was tried in a few cities and found to be helpful. In two small communities water was pumped into the system for a short period in the morning and again in the evening. Needless to say, this offers serious hazards to water quality, but with this method, almost any degree of conservation, up to 100 per cent, can be obtained.

During 1951-54, industries have learned much about conserving water. For example, three refineries at Augusta and El Dorado reduced their water use from 53 to 48, 129 to 60 and 160 to 62 gallons respectively, per barrel of crude oil processed. A refinery at McPherson reduced its process water use from 216 to 75 gallons per barrel of crude because of a water shortage. These savings in water were through recycling, changing of piping to prevent contamination of water formerly given a single pass through the plant and the treatment of contaminated wastes for reuse. The extent of these savings is shown by comparison with Ohio River Valley refineries which use an average of 770 gallons of water per barrel of crude.

The aircraft industries at Wichita reduced their water use by more than 50 per cent without adversely affecting their production, and several industries used municipal sewage treatment plant effluent for process purposes.

Variations and Trends in Water Consumption

Population and water use data for eight typical cities are shown in Figures 2 and 3 to illustrate the increasing demands upon public water systems since 1925. These curves, which show a steady per capita increase and also a steady increase in population, are most significant because of the increasing spread between maximum and average daily water use since 1949. This is an experience typical of virtually all cities in Kansas. Fluctuations in water use, particularly in the maximum daily consumption, can be traced to economic conditions, restrictions during the war and effects of the weather. Since the average annual rainfall in Kansas varies from less than 20 to more than 40 inches per year, from west to east, the per capita water consumption is higher in the western part of the state.

A study of the records of Wichita's domestic metered consumption made in 1952 showed that over a 30-year period the winter per capita use of water had increased 80 per cent. Most of this increase is attributed to new water using appliances. The domestic water use increase of 125 per cent during summer months reflects the demand for water for air conditioning and lawns. In 1922 summer demand for water was about 1.5 times as great as in the winter months. In 1952 the ratio of summer to winter demand had risen to 1.9.

The current municipal use of water in Kansas is 155 gallons per capita per day, slightly below the national average of 160 gallons. A survey of all municipal water supplies in Kansas made in connection with preparation of the report "Water in Kansas" estimates the total use of Kansas public water supplies in 1975 at 335 million gallons per day or a per capita use of 185 gallons per day.

Marked variations from hour to hour, day to day and season to season are common in municipal waterworks operation. As indicated in Figures 2 & 3, the maximum daily use prior to 1950 was generally not more than 1.5 times the average daily use. However, the maximum day has been increasing more rapidly and in several cities the peak daily demand in 1954 was more than three times the average daily use. Peaks in the maximum day make it necessary that a system deliver up to five times the average daily use for periods of several hours.

The use of water for air conditioning is primarily responsible for the increased peak demand in recent years. More and more cities are regulating the use of water for air conditioning purposes. Since nonconserved air conditioners require about 1150 gallons of water per day per ton of capacity, and conserved conditioners need only 60 gallons per day for the same capacity, cities are adopting ordinances requiring conserved use for units larger than 2 tons.

Large expenditures will be required to keep up with the growth in water demand. On the basis of today's prices, about 118 million dollars must be spent in Kansas during the next 20 years for expansion. Of this amount, $34,400,000 will be used for new sources of supply and the remaining $83,600,000 will be spent in improving purification, storage, pumping and distribution facilities.(7)

Reasons for the Inadequacies

The 175 municipal water shortages were caused by a series of events. First, more than normal rainfall from 1941 through 1951 made the gradually increasing water use seem less significant than it actually was. Second, higher temperatures, beginning in 1952, caused more water to be used for air conditioning, lawn watering and park maintenance. Population growth and failure to correct deficiencies which occurred during World War II also contributed importantly to the shortages.

An analysis of the shortages shows that in nearly two-thirds of the cities primary cause was the lack of foresight and planning.

In an additional 42 communities, problems of finance were the primary cause of shortages; most of these are small towns. While Kansas financing laws for waterworks are considered to be adequate, these communities face unusual financial burdens because of no nearby source of water supply. In 7 cities a geologic study revealed ground water which the city had not known existed.

Unusual growth in water demand was the primary cause of shortage in only 6 communities. The largest of these was Wichita. The seven cities listed in the "other" category in Table III were either new systems whose newly constructed reservoirs had not filled, or systems which for some other reason did not fall in any of the other 4 categories. Yates Center, for example, is included in this tabulation since its reservoir had adequate storage, but much of the water in the reservoir was drained to permit repairs to the spillway. In most of the 113 cities where lack of foresight and planning were the

TABLE III. Causes of Water Shortages

Source	Cities with Shortage '53-'54	Primary Cause of Shortage: Unusual Growth in Demand	Lack of Foresight &Planning	Inadequate Finance	Lack of Information on Water Available	Other
Surface	40	0	16	3	0	5
Ground	135	6	97	39	7	2
Total	175	6	113	42	7	7
Per Cent	100	3.4	64.6	24	4	4

primary cause of the shortage, both officials and citizens share the responsibility for the shortage. In 8 cities, however, 6 of them surface supplies, waterworks officials and engineers had anticipated shortages, but their advice was not heeded by the community. In general, it appears that where substantial changes are needed in the source of supply, treatment facilities, pumping or the distribution network, a minimum of 3 to 5 years is needed to obtain public approval and build the new facilities.

Of the 175 inadequate supplies, 116 inadequacies were caused primarily by lack of capacity at the wells. Many of this group also had lacked sufficient pumping, storage or distribution capacity. A breakdown of the inadequacies is given in Table IV.

TABLE IV. Physical Inadequacies of 175 Public Water Supplies.

Inadequacy	Number of cities Affected		Total Population Affected	
Source of supply*				
Reservoirs	17		51,800	
River or stream impoundment	15		54,600	
Wells	116		367,400	
Subtotal		148		473,800
Pumping capacity only	14		59,900	
Treated water storage capacity only	3		1,900	
Distribution system only	1		1,700	
Combination of pumping, storage, treatment plant, and/or distribution system capacity (source adequate)	8		61,200	
Total	174		598,500	

*Many of these systems also had inadequate capacity in pumping, storage, treatment, and distribution.

Effect of Drought on Design and Practice

As the period of drought continues into 1955 it promises to revise practice particularly in the design of impoundments and on the sizing of water storage, purification and distribution facilities. While the annual rainfall during 1952-53 averaged from 60 to 65 per cent of normal, the number of storms of sufficient magnitude to produce runoff were less than 10 per cent of normal. It

is doubtful that any of the water shortages to date can be laid to inadequacies in engineering design, in spite of these facts. Nevertheless, deficiencies are apparent in available data upon which to base the design, particularly as they relate to the need for more exact figures on rainfall, runoff, stream flow, evaporation and reservoir silting.

The average annual precipitation since 1890, as shown in Figure 1, seems to indicate alternate wet-dry cycles, each of 10 to 13 years duration. The usual occurrence of a wet year in the middle of the dry cycle, and occasional intense storms, makes the design of reservoirs on the basis of a 3 to 4 year drought practicable except for the smallest catchment areas. Where possible the design should be based upon actual rainfall and runoff records for the specific watershed, but since this is often impossible, a comparison with other watersheds and with other projects is necessary.

Figure 4 compares the state-wide deficiency in precipitation for the present dry cycle with the most severe previous drought of record, 1932 to 1935. On the basis of the state-wide average at the end of 1954, the current drought may be more severe and may require a more conservative approach to reservoir design than necessary on the basis of experience in the 1930's.

Improved farming practice such as contour farming, terracing, and the construction of farm ponds has decreased the yield which can be expected from a catchment area, particularly during dry seasons. Farm ponds must be filled before runoff occurs below them, and undoubtedly more of the moisture held behind terraces is lost to transpiration and evaporation. The rate at which silt accumulates in reservoirs should be reduced by improved watershed practice. Silting has contributed to some of the water shortages and has resulted in storage depletions varying from 0.25 to 5 per cent per year.

The drought has pointed out the importance of providing adequate chlorination capacity, chemical feed facilities, mixing and settling times in the plant which treats surface water. That several cities have been required to treat raw water of considerably different quality than anticipated at the time their water plants were built demonstrates the value of a flexible water plant, conservatively designed.

CONCLUSION

Past rainfall and stream flow records clearly show that droughts recur, and that the present drought may not be broken for several years. That another drought with characteristics similar to the present one will occur is mathematically certain. At the same time steady population growth and the increased per capita use of water makes continually growing demands upon water pumping, treatment and distribution facilities. These droughts are the periods for which waterworks designers must prepare. To conserve the fresh water, increasing attention to the treatment of sewage and industrial wastes will be necessary.

That the majority of the water shortages were caused by failure of the communities to act rather than through lack of water at the source points up the importance of long-range, professional planning at least five years in advance of the needs.

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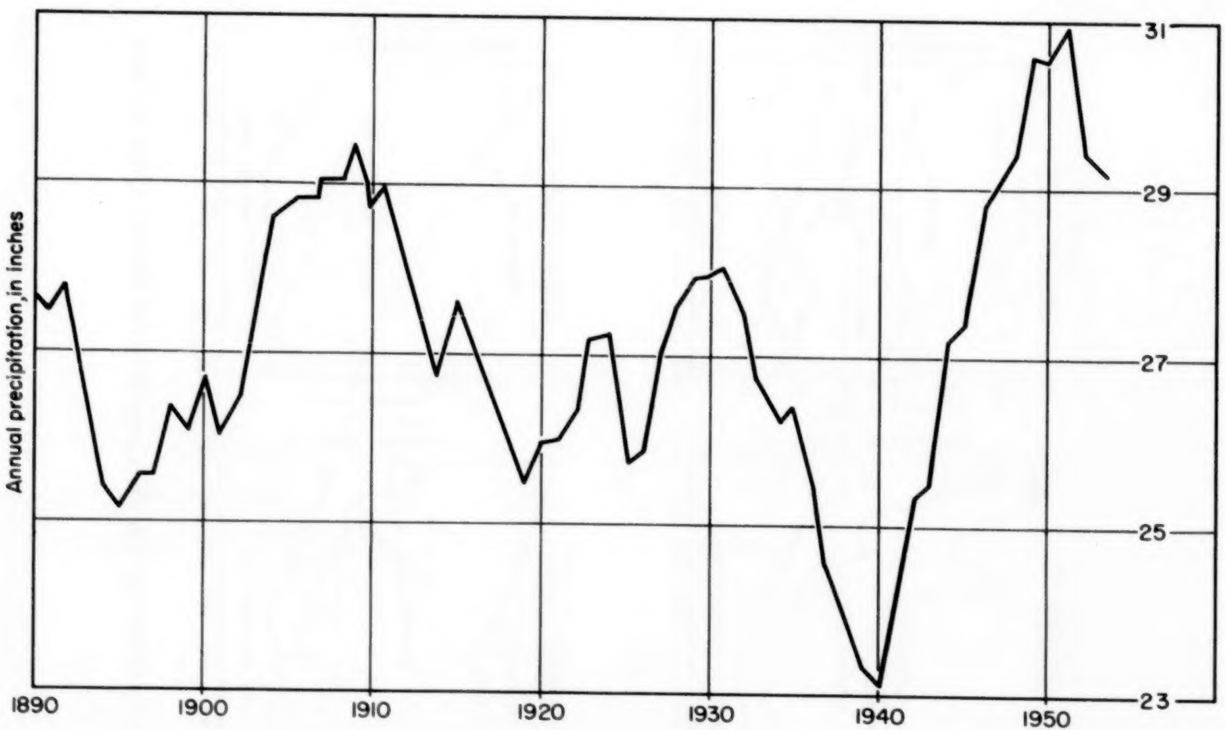

FIGURE 1.—AVERAGE ANNUAL PRECIPITATION, 1890–1954

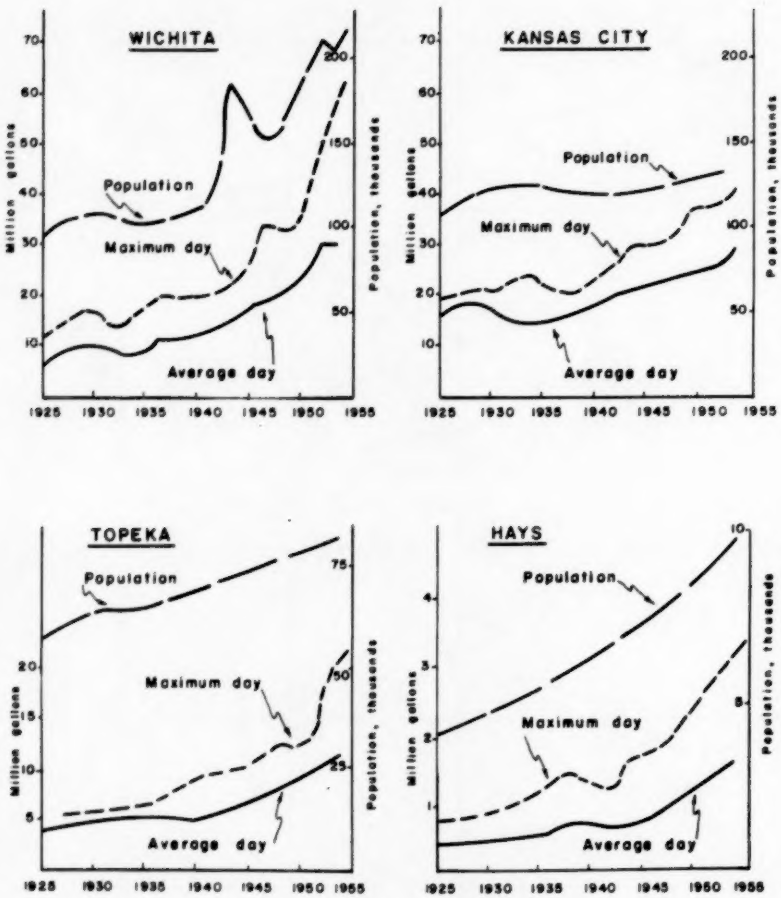

FIGURE 2. — WATER USE AND POPULATION DATA FOR SEVERAL CITIES IN KANSAS

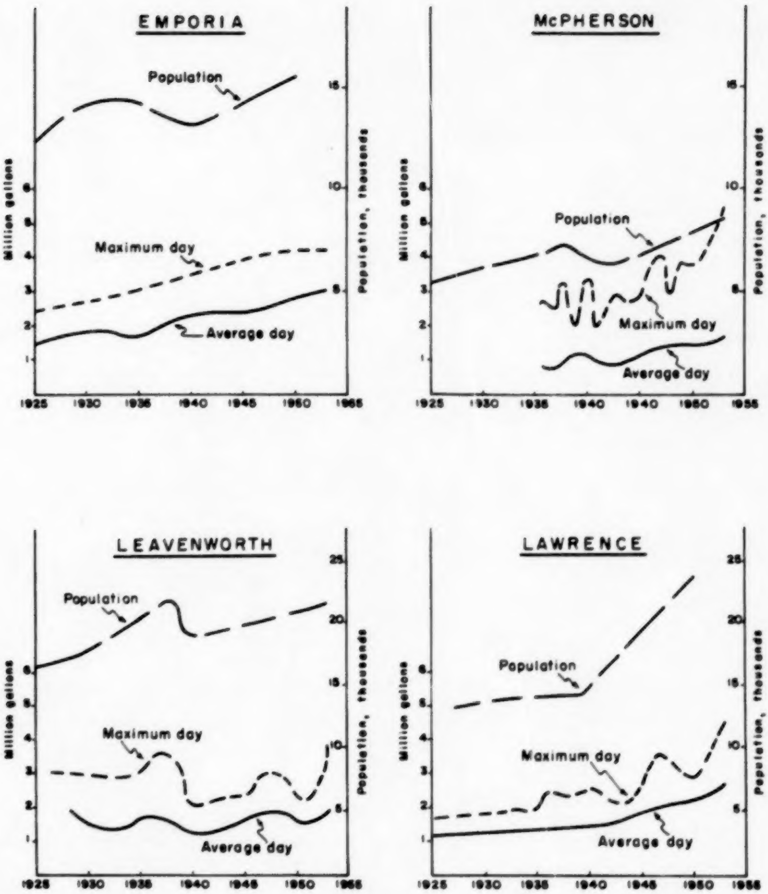

FIGURE 3. — WATER USE AND POPULATION DATA FOR SEVERAL CITIES IN KANSAS

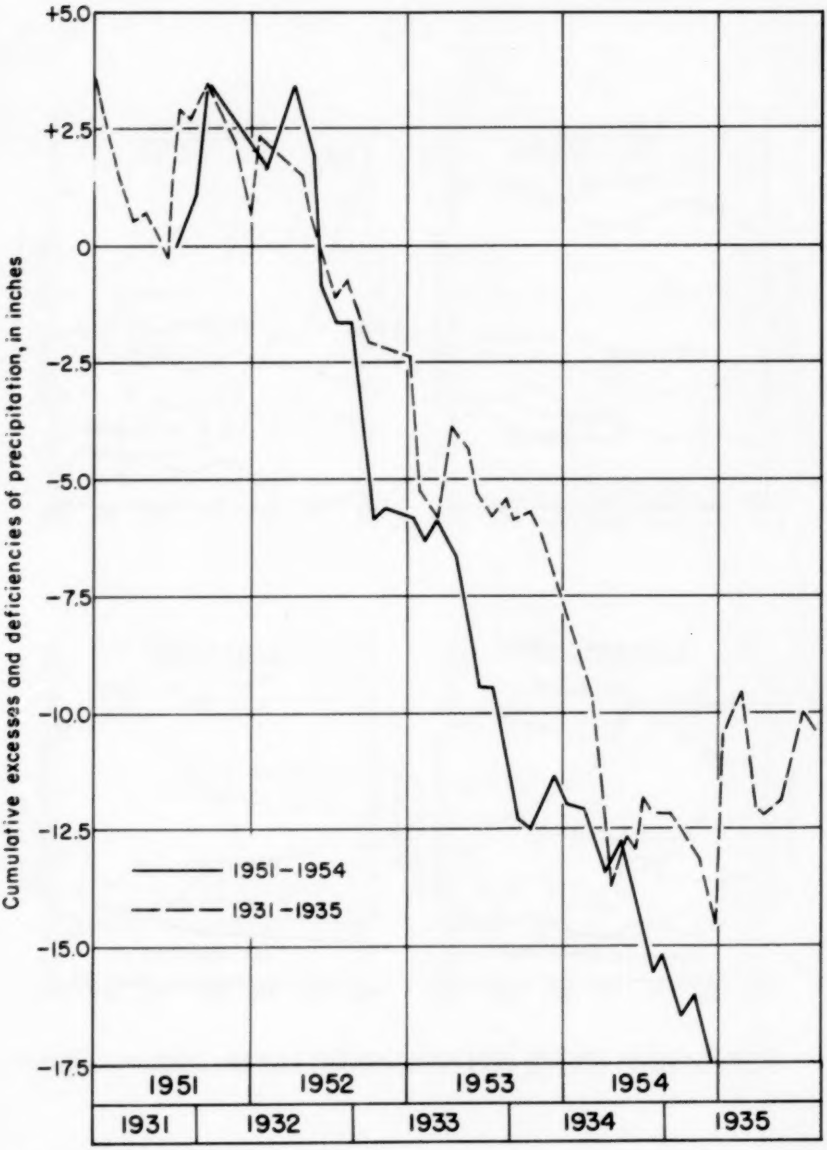

FIGURE 4.– DEFICIENCY TRENDS IN TWO MAJOR DROUGHTS